

and insert --of the etching chamber in a range--~~t~~, same line

10, after "120 °C" insert --,--;

Line 11, delete "the";

Line 12, delete "the" and insert --a--, same line 12, after  
"and" insert --a--;

Line 14, after "and" insert --,--;

Line 15, after "also" insert --,--, same line 15, delete "a"  
and insert --the--;

Line 16, delete "an" and insert --a simplified--;

Line 17, delete "performed" and insert --obtained--.

#### REMARKS

The specification and abstract of the disclosure have been amended to correct errors of a typographical and grammatical nature. Due to the excessive corrections thereto, applicants submit herewith a Substitute Specification, along with a marked-copy of the original specification for the Examiner's convenience. Applicants submit that the substitute specification includes no new matter. Therefore, entry of the Substitution Specification is respectfully requested.

The claims have also been amended to more clearly describe the features of the present invention.

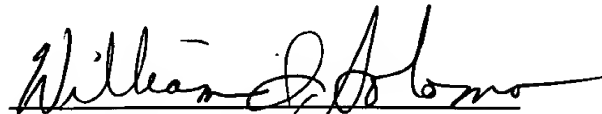
Entry of the preliminary amendments and examination of the application is respectfully requested.

To the extent necessary, Applicants petition for an extension of time under 37 CFR § 1.136. Please charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to the Deposit Account No.

01-2135 (Case No. 503.37698X00) and please credit any excess fees to such Deposit Account.

Respectfully submitted,

ANTONELLI, TERRY, STOUT & KRAUS, LLP



William I. Solomon  
Registration No. 28,565

1300 North Seventeenth Street  
Suite 1800  
Arlington, VA 22209  
Tel.: 703-312-6600  
Fax.: 703-312-6666

WIS/DRA/slk



Title of the Invention:

A PLASMA PROCESSING APPARATUS AND A PLASMA  
PROCESSING METHOD

5 Background of the Invention:

The present invention relates to a plasma processing apparatus and a plasma processing method; and, in particular, *the invention relates* [particularly] to an apparatus for etching an insulation film, such as a silicon oxide film of a wafer, using a plasma. *The invention* 10 plasma [and] relates to a plasma etching apparatus and a plasma etching method having a plasma generation source which *is capable of effecting* [can be corresponded to] a minute *processing* [practicing] of an etching pattern, and, further, *is* [enable for maintaining] a stable etching characteristic during a long period. *of operation*

15 *One example of a* [Among] conventional plasma processing apparatuses *is* [an oxide film plasma etching apparatus] *is exemplified*, and *the* techniques, and, problems *used thereby the inherent in known* [of] this apparatus are [shown]. As *a for use in* [the] conventional plasma source [of] an oxide film [use] plasma etching apparatus, a type which is used most widely is a

20 narrow electrode type high frequency plasma generation apparatus, which is comprised of a pair of [opposing] *opposed* electrodes.

*Of the known* [The] systems of the narrow electrode type *of* high frequency plasma generation apparatus *have known that*, 25 there is a system in which a high frequency [having] from 13.56 MHz to a several 10 MHz [degree] is applied to one electrode and [to another electrode by mounting a wafer] a

high frequency bias (having<sup>of</sup> about 1 MHz [to the wafer] is applied separately, and there is another system in which a high frequency is applied to <sup>the</sup> [a] pair of electrodes.

In this, <sup>narrow electrode type of</sup> plasma source [system] etching apparatus, since <sup>the</sup> [a] distance between the electrodes is narrow, <sup>for example,</sup> from 20 mm to 30 mm, it is <sup>known</sup> [called] as a narrow electrode type plasma source and a parallel flat plate type plasma source.

Further, in the narrow electrode type plasma source, it is difficult to generate a plasma [generation at] <sup>in</sup> a region where <sup>the</sup> [a] pressure is low, however, by <sup>the</sup> [an] addition of [a function of] a magnetic field [application etc.], an apparatus <sup>is obtained</sup> in which a lowering of <sup>the</sup> [a] discharge pressure [is] <sup>can be achieved</sup> [improved is used].

Further, <sup>in</sup> addition to the above-stated apparatus, <sup>narrow electrode type of</sup> other plasma etching apparatuses have <sup>been</sup> known. <sup>These</sup> these apparatuses include a <sup>are</sup> one plasma etching apparatus having an induction type plasma source in which an induction coil is used and another plasma etching apparatus <sup>in which</sup> (having) a [microwave] plasma etching microwave is introduced.

In these <sup>apparatuses having an</sup> induction type etching source and <sup>source</sup> [the] a microwave type plasma [sources], it is possible to generate and maintain the plasma under a low pressure; and <sup>further,</sup> since <sup>the</sup> [a] plasma density is high, <sup>such a</sup> [the above-stated] plasma source is <sup>known</sup> [called] as a low pressure and a high density plasma source.

In [a] silicon oxide film etching, as an etching gas,

one mixture gas, in which to argon (Ar), a gas including carbon (C) and fluorine (F), such as  $C_4F_8$ , and a gas including hydrogen (H), such as  $CHF_3$ , are mixed, is used; and, further, another mixture gas, in which oxygen ( $O_2$ ) and a carbon monoxide ( $CO$ ) and hydrogen ( $H_2$ ) etc. are added, the above-stated one mixture gas, is used.

These gases are dissociated by the plasma and dissolved to  $CF_3$ ,  $CF_2$ ,  $CF$ , and  $F$ . The amount and the ratio of this gas molecule species gives largely an influence on the etching characteristic of the silicon oxide film (hereinafter, it is called merely as an "oxide film").

In particular, in the case of the high density plasma source, since the electron temperature in the plasma is high, the plasma dissociation is progressed, and the plasma has many fluorine gas molecule kind  $F$ . Further, as the ionization progresses, it has a feature in which the ratio of a neutral gas molecule species (radicals) becomes low.

With these reasons, in the oxide film etching according to the high electron temperature and the high density plasma, since the amount of  $CF_x$  ( $CF_3$ ,  $CF_2$ ,  $CF$ ) which adheres to a silicon surface, which is a foundation of the oxide film, is lowered, there are problems in which the etching speed of silicon (Si) is large and the selection ratio is small.

As means for solving the above stated problems, a method for increasing the  $CF_x$  radical amount in the plasma

been in which the <sup>4</sup> the the  
has, known, [namely a] temperature of [a] wall face of [an]  
etching chamber is [risen] <sup>raised</sup> to about 200 °C, [and a] <sup>in an effort to discharge the</sup>  
deposition film which <sup>has</sup> [is] adhered to the wall face [is]  
[tried to discharge, and an] <sup>by reducing the</sup> adhesion [to] the deposition  
5 film to the wall face of the etching chamber [is]

[restrained].  
As a result, in [the] <sup>an</sup> apparatus in which [the] <sup>a</sup> high  
density plasma is used, to obtain the <sup>desired</sup> selection ratio, a  
high temperature performance of the wall face of the  
10 etching chamber becomes indispensable.

An oxide film etching apparatus described in  
Japanese application patent laid-open publication No. Hei  
7-183283 is an example <sup>of an apparatus in which</sup> [where] a wall face of an etching  
chamber is formed <sup>to have a</sup> [with the] high temperature performance.

15 As a countermeasure for obtaining the high selection  
ratio in addition to the above technique, <sup>there is a</sup> [it has] known [a]  
method in which <sup>the</sup> [an] electron temperature in the plasma is  
lowered and [a] plasma dissociation is restrained. <sup>In</sup> <sup>More specifically</sup>  
concretely, <sup>in this method the</sup> [a] plasma application is carried out  
20 intermittently, and <sup>so</sup> this method is called [as] a pulse  
plasma method.

As another one example <sup>of</sup> [for] obtaining [the] <sup>a</sup> high  
selection ratio, there is a method in which materials for  
consuming [the] fluorine (F) are installed in an etching  
25 chamber in advance. In Japanese application patent laid-  
open publication No. Hei 9-283494, [the above stated] <sup>such a</sup>  
method is, <sup>described</sup> [shown], <sup>in which</sup> a side wall of an etching chamber is

5

constituted by silicon (Si), <sup>and</sup> a heating means <sup>for heating</sup> [of] the side wall and a bias application means are provided, <sup>so that</sup> [and] the fluorine (F) in the plasma is consumed.

In [the] oxide film etching in which [the] narrow electrode type <sup>of generation</sup> plasma is used, in correspondence with the fine <sup>patterning</sup> [practicing], in which a device pattern size [moves to] <sup>is</sup> less than  $0.25\ \mu\text{m}$ , [to a portion to be subjected the] [etching] it is necessary to make <sup>the</sup> extremely small <sup>a</sup> scattering of <sup>the</sup> [an] ion incident angle. <sup>at a portion to be subjected to the etching extremely small</sup>

10 Since the scattering of the ion incident angle causes an abnormality of <sup>the</sup> [an] etching shape and <sup>a decrease in the number of ions</sup> [an ion] <sup>the</sup> [amount for] reaching [to a] bottom of a deep hole <sup>are caused including</sup> [is] [decreased], [there are] problems, [in which] a lowering of <sup>premature stopping</sup> [an] <sup>in the formation of holes</sup> etching speed <sup>is caused</sup> [is caused] and a [stop] of the etching <sup>is</sup> [caused].

15 [The] <sup>this</sup> scattering of the ion incident angle is caused by [the cause in which an] <sup>the</sup> incident angle distribution <sup>has</sup> [has] <sup>having</sup> a spread angle because the ions collide with [the] radicals in the plasma. <sup>P</sup> To solve the above stated problems, it is effective to decrease the <sup>number of collisions between ions and</sup> [collision of the ion with the] radicals, <sup>more particularly,</sup> in concretely, it is necessary to lower the pressure.

20 As a result, in the narrow electrode type <sup>of</sup> plasma generation apparatus <sup>because it is difficult to carry out</sup> [in which] the plasma discharge <sup>is</sup> [is] <sup>conditions</sup> [difficult to carry out] under (the) low pressure, even under (the) <sup>a</sup> low pressure <sup>sufficient to</sup> [enable for] generate <sup>a</sup> [the] plasma, <sup>it</sup> [there] is <sup>proposed</sup> [devised] that the frequency of the plasma generation

source <sup>be</sup> [is] made <sup>be</sup> [to the] high [frequency] and <sup>that a</sup> [the] magnetic field <sup>be</sup> [is] applied.

Further, in the narrow electrode type <sup>of</sup> plasma source in which the distance between the electrodes is narrow, in a case where <sup>a</sup> [the] low <sup>pressure</sup> [pressurization] is <sup>used</sup> [devised], since <sup>the</sup> [an] average free <sup>path distance</sup> [stroke] of the gas <sup>molecules</sup> [molecule] becomes long, the collision frequency of the gas molecules <sup>together</sup> [together] <sup>and,</sup> [with] is decreased, <sup>and,</sup> in place of this, the collision between the gas molecules and the electrode becomes <sup>dominant</sup> [dominate].

10 This is not a preferable condition, <sup>since, in</sup> [as] the etching apparatus, <sup>in which</sup> according to the collision of the gas molecules in the plasma, it is necessary to control the maintenance and the reaction of the plasma <sup>in order</sup> [and], as a result <sup>in order</sup> [so as] to <sup>accommodate a</sup> [correspond] the low pressurization, it is <sup>provides a</sup> necessary to <sup>provides a</sup> [form] large [the] electrode interval.

When the electrode interval is [formed] wide, <sup>the surface</sup> [a rate] <sup>Here, the</sup> [of an] area of the side wall <sup>is the surface</sup> [which] occupied with a surface <sup>include</sup> [area] in the etching chamber becomes large. <sup>the</sup> [The] surface of the etching chamber <sup>the</sup> [indicates one] which is subjected to the plasma, and the surface does not <sup>the</sup> [a surface of] [a] top plate <sup>the</sup> [a] ceiling), a surface of <sup>the</sup> [a] floor, and a surface of the electrode (the wafer).

Until now, in the narrow electrode type plasma source, <sup>the</sup> [viewing] from <sup>at</sup> [an] aspect of the plasma and a wafer, 25 since the side wall area is narrow, the deposition and the gas discharge <sup>on</sup> <sup>have almost no</sup> [in] the side wall, <sup>on</sup> [do not almost give the] influence <sup>on</sup> [to] the etching characteristic; however, in the



narrow electrode type plasma apparatus in which <sup>a</sup>the low pressurization is <sup>used</sup> ~~devised~~, it is necessary to take a new countermeasure.

Further, to <sup>accommodate</sup> ~~correspond to~~ a large diameter ~~sizing of~~ <sup>make the</sup> the wafer, it is necessary to <sup>uniform</sup> ~~uniform~~ a gas pressure distribution <sup>across the</sup> ~~in a~~ wafer face and <sup>the</sup> ~~a~~ reaction product distribution, and, for this purpose, it is necessary to <sup>uniform</sup> ~~form~~ provide a wide ~~the~~ electrode interval, and <sup>so</sup> ~~an~~ importance of <sup>important</sup> the area ratio of the side wall becomes <sup>reaction products</sup> ~~high~~ more and more.

10 The influence of the affects of <sup>adhere</sup> ~~the~~ react product which <sup>on</sup> ~~is adhered~~ to the side wall <sup>discussed</sup> ~~to~~ the etching characteristic is <sup>discussed</sup> ~~shown in~~ above, however, when the etching is continued ~~extending~~ over <sup>of time</sup> ~~during~~ a long period, a change of the influence ~~degree~~ becomes a problem.

15 For example, by <sup>repeatedly</sup> ~~carrying out~~ ~~repeatedly~~ the etching operations, the temperature of the side wall <sup>will rise</sup> ~~is risen~~ gradually. When the temperature of the side wall <sup>has sufficiently</sup> ~~is risen~~, the characteristic of the adhesion and adsorption of the <sup>reaction products on</sup> ~~reaction product to~~ the side wall <sup>and</sup> is changed, as a result, 20 the etching characteristic <sup>fluctuates</sup> ~~is fluctuated~~.

Further, in a case where the amount of the deposition film <sup>on</sup> ~~to~~ the side wall accompanying ~~with~~ the etching is increased gradually, in accordance with the dependence <sup>on</sup> ~~to~~ the amount of the deposition film, it is 25 possible to change the desorption and adsorption characteristic of the reaction <sup>products</sup> ~~product~~ at the side wall surface.

A phenomenon in which the etching characteristic <sup>is influenced by the</sup> receives the influences according to the time lapse change stated [in] above is known [in] particularly in the case of [the] oxide film etching. As a result, the temperature <sup>change</sup> [adjustment] of the side wall in the oxide film etching apparatus <sup>represents</sup> [is] an important problem.

In <sup>particular</sup> [particularly], in <sup>a</sup> [the] high electron temperature and high density plasma source, it is <sup>necessary</sup> [compelled] to establish <sup>a high</sup> [the] side wall temperature <sup>case of a</sup> [high]. In the <sup>above</sup> [above] <sup>stated</sup> [stated] high side wall temperature, even the side wall temperature <sup>fluctuates</sup> [is fluctuated] a little, <sup>and so</sup> the adsorption and desorption characteristic of the deposition film is changed largely.

<sup>for</sup> [With] these reasons, it is necessary to restrain the side wall temperature fluctuation <sup>to</sup> [in] a small range, and <sup>a</sup> [the] high accuracy temperature adjustment, such as  $200\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$  <sup>needs to be</sup> [is] carried out.

As stated [in] above, in any of the plasma sources, to satisfy the requirement <sup>for</sup> [of the] oxide film etching, namely <sup>a</sup> [the] obtaining [the] high etching speed <sup>while</sup> [by] attaining <sup>a</sup> [the] high selection ratio, <sup>and</sup> [the] low micro loading, the passing-through of <sup>a</sup> [the] deep hole, <sup>there still remain problems</sup> [it] remains the problem to be solved.

\* The important problem in <sup>an</sup> [the] oxide film etching apparatus <sup>involves</sup> [is that] the dissociation of the gas <sup>molecules</sup> [molecule] <sup>as</sup> [according to] the plasma is <sup>being</sup> formed <sup>under the</sup> [as a] most suitable <sup>conditions for</sup> [condition in] the etching of the oxide film. To

<sup>address problem</sup>  
 [correspond to] this, [it has proposed] a new plasma  
 generation source <sup>producing</sup> [having] a high density plasma under <sup>a</sup> low  
 electron temperature <sup>has been proposed</sup>.

For example, [as described in] Japanese application  
 5 patent laid-open publication No. Hei 8-300039, <sup>discloses a</sup> [there is] a  
 UHF type ECR apparatus having a plasma excitation  
 frequency <sup>in the</sup> [of] UHF band from 300 MHz to 1 GHz. <sup>The</sup> [An] electron  
 temperature of the plasma which is excited <sup>in</sup> [by] the  
 frequency band <sup>in</sup> [having] the above stated range is low, <sup>for example,</sup> from  
 10 0.25 eV to 1 eV, and the plasma dissociation of  $C_4F_8$  <sup>is at</sup> [has] a  
 level [for] <sup>an</sup> suitable to [the] oxide film etching. Further,  
 since it is <sup>an</sup> ECR (Electron Cyclotron Resonance) system,  
 even under [the] <sup>a</sup> low pressure, it is possible to generate  
 [the] <sup>a</sup> high density plasma.

15 As stated <sup>achieving</sup> [in] above, for [the] correspondence to the  
 fine <sup>patterning on a</sup> [practicing] and the wafer, large diameter [sizing], it  
 is necessary to make the electron temperature low and to  
<sup>prevent an excessive</sup> [restrain the excess] dissociation of the etching gas, and  
 further to make the plasma density high.

20 Further, it is necessary to <sup>make</sup> [uniform] the plasma  
 density, the gas pressure and the reaction product  
 distribution on the wafer <sup>uniform;</sup> and, as a result, it is  
 necessary to provide an apparatus in which <sup>the</sup> [an] oxide film  
 etching characteristic is not changed [extending] over  
 25 [during] a long period <sup>of operation</sup>.

## Summary of the Invention:

5 <sup>It is an</sup> (An) object of the present invention to provide a plasma processing apparatus and a plasma processing method, wherein, using <sup>a</sup> UHF type ECR plasma etching apparatus <sup>to</sup> [enable for] generate a high density plasma under a low electron temperature necessary for (an) oxide film etching etc., a fluctuation of <sup>the</sup> (an) etching characteristic can be restrained (small extending over) <sup>of operation</sup> during a long period.

10 Another object of the present invention <sup>is</sup> to provide a plasma processing apparatus and a plasma processing method, wherein, using <sup>a</sup> UHF type ECR plasma etching apparatus <sup>to</sup> [enable for] generate a high density plasma under a low electron temperature necessary for (an) oxide film etching etc., a <sup>premature stopping</sup> (stop) of (an) etching <sup>the</sup> [is not generated] <sup>does not occur</sup> and in which <sup>processing</sup> (also) a stable operation or a stable (work) can be carried out.

20 The characteristic <sup>feature</sup> according to the present invention <sup>resides</sup> (is that) in a plasma processing apparatus <sup>and</sup> (or) in a plasma processing method using a vacuum processing chamber, a sample table for mounting a sample which is processed in said vacuum processing chamber, and a plasma generation means, [the plasma processing apparatus], wherein, when [a] plasma processing is carried out by <sup>by</sup> generating a plasma [according to an] introduction of a gas which contains at least carbon and fluorine, <sup>into the processing chamber</sup> and by which <sup>is generated</sup> (generating) a gas species, which contains carbon and

fluorine according to a plasma dissociation, said plasma generation means <sup>being</sup> [is] a plasma generation means in which [a] <sup>the</sup> degree of [said] plasma dissociation is <sup>in</sup> a middle <sup>range</sup> [degree] and said gas species containing [the] carbon and [the] fluorine <sup>wherein the</sup> is generated fully in the plasma, and [a] temperature of a region which forms a side wall of said vacuum processing chamber is controlled to have a range of 10 °C to 120 °C.

In <sup>a</sup> UHF type ECR plasma etching apparatus <sup>having</sup> [has] a UHF band microwave radiation antenna <sup>disposed</sup> at <sup>a</sup> [an] opposite <sup>opposite</sup> position <sup>the</sup> to [a] wafer, <sup>an etching gas is supplied</sup> [and] from a gas supply portion provided on an antenna portion [an etching gas is supplied]. The UHF band microwave is radiated directly to <sup>the</sup> [a] plasma from the antenna and is radiated in the plasma through a dielectric body which is provided at a periphery of the antenna.

In an electrode for mounting the wafer (a wafer mount electrode or a lower electrode), an etching position and a wafer delivery position are <sup>located</sup> [positioned] at separate <sup>locations,</sup> [positions] and an electrode <sup>raising</sup> [ascent] and <sup>lowering</sup> [descent] function is provided. A distance <sup>interval</sup> (<sup>it is</sup> called [as] an "electrode <sup>electrode</sup> [between distance]") between the wafer mount <sup>electrode</sup> [wafer] and the antenna or the gas supply plate is established <sup>as</sup> [from] 50 mm to 100 mm taking into [the] consideration [about such a] re-association of <sup>the</sup> [a] reaction <sup>products</sup> <sup>product</sup>.

According to the plasma processing apparatus, a side wall temperature at a periphery of the electrode is

temperature adjusted <sup>within</sup> (with) a range of 10 °C to 120 °C, preferably a range of 30 °C to 50 °C. <sup>As the</sup> (The) side wall temperature <sup>fluctuates</sup> is fluctuated, a gas species is discharged from a deposition film <sup>on</sup> (of) the side wall, and this <sup>has</sup> (gives) an influence <sup>on the</sup> (of an) etching characteristic.

5 In <sup>accordance with</sup> the present invention, to restrain the above stated influence, <sup>the</sup> (a) temperature control accuracy of the side wall is controlled <sup>to</sup> (at)  $\pm 5$  °C. Since the side wall temperature is low, even <sup>when</sup> the temperature of the side wall <sup>fluctuates by</sup> is fluctuated be at 5 °C degree, (since) the fluctuation of a discharge gas amount which is discharged from the side wall, <sup>will be small so that</sup> the influence on the etching characteristic can be neglected.

15 Further, since the plasma source is <sup>a</sup> UHF type ECR system, <sup>the</sup> (a) plasma dissociation is <sup>in</sup> a middle <sup>range</sup> (degree) and <sup>a</sup> CFx species exists fully to a level necessary for the oxide film etching. <sup>Since the problem of</sup> (since) a shortage of CFx species and an excess F, which <sup>is inherent</sup> (becomes the problems) in <sup>a</sup> (the) high density plasma source, can be solved, <sup>increase</sup> (and) to <sup>increase</sup> (heighten) the selection ratio, it is unnecessary to <sup>increase</sup> (heighten) the side wall temperature.

20 Herein, when the dissociation <sup>is excessive,</sup> (exceeds over) F or C becomes rich, and when the dissociation <sup>insufficient,</sup> is <sup>there is a shortage of</sup> (short) F, CF<sub>2</sub>, CF<sub>3</sub>, etc (become the shortage), accordingly, it is desirable to have <sup>a</sup> (the) plasma dissociation <sup>fall in</sup> (with the) middle <sup>range</sup> (degree).

Further, since the side wall temperature is controlled <sup>to a</sup> (the) low temperature, <sup>with a</sup> (even the) side wall temperature

control accuracy <sup>of</sup> (is)  $\pm 5$  °C, the fluctuation of the etching characteristic can be restrained <sup>for</sup> (at) a long period <sup>of operation</sup>.

#### Brief Description of Drawings:

5 Fig. 1 is a schematic <sup>sectional diagram</sup> [view] showing an etching apparatus of a plasma processing <sup>system representing</sup> [apparatus and a plasma] [processing method of] one embodiment according to the present invention;

10 Fig. 2 is a <sup>graph</sup> [view] showing a size relationship of various kinds of plasma sources of a plasma processing apparatus and a plasma processing method [of one] [embodiment] according to the present invention;

15 Fig. 3 is a <sup>graph</sup> [view] showing a characteristic of a gas discharge from a deposition film of a plasma <sup>source</sup> [sources] of a plasma processing apparatus and a plasma processing method [of one embodiment] according to the present invention;

20 Fig. 4 is a <sup>graph</sup> [view] showing <sup>the</sup> (an) influence of a side wall temperature (which gives an influence to <sup>on</sup> a time lapse change of a plasma <sup>source</sup> [sources]) of a plasma processing apparatus and a plasma processing method [of one] [embodiment] according to the present invention;

25 Fig. 5 is a <sup>graph</sup> [view] showing an etching speed change in a case where a temperature adjustment of a side wall is not performed [according to the prior art]; and

Fig. 6 is a <sup>graph</sup> [view] showing an etching speed change in a case where a temperature adjustment of a side wall is

performed according to the present invention.

*an Embodiment of*  
Description of the Invention:

Hereinafter, a plasma processing apparatus and a  
5 plasma processing method <sup>representing</sup> (of) one embodiment according to  
the present invention will be explained.

Fig. 1 is an example of <sup>a</sup> UHF type ECR plasma etching  
apparatus. At a peripheral portion of an etching chamber  
1 (a vacuum processing chamber), which is <sup>operated as</sup> a vacuum  
10 vessel, a coil 2 is installed, <sup>and</sup> this coil 2 generates an  
electron cyclotron resonance (ECR) <sup>use</sup> field.

An etching <sup>use</sup> gas is supplied from a gas supply  
pipe 3 and is introduced <sup>via</sup> [to from] a gas supply plate 4 to  
the etching chamber 1. The gas supply plate 4 is  
15 comprised of a plate <sup>made</sup> of [a] silicon <sup>form</sup> or a glass form  
carbon in which about 100 [number] fine holes having a  
diameter of from 0.4 mm to 0.5 mm degree are provided.

At an upper portion of the gas supply plate 4, a  
<sup>shaped</sup> disc <sup>form</sup> antenna 5 is provided, and this antenna 5  
20 radiates <sup>energy in the</sup> [a] microwave <sup>energy is supplied</sup> (having) UHF band. The microwave, to  
the antenna 5 <sup>is supplied</sup> from a power supply 6 through  
an induction shaft 7.

When the microwave <sup>energy</sup> is radiated from a periphery of  
the antenna 5, an oscillating electric field <sup>in a</sup> (of an upper)  
25 space <sup>above</sup> (of) the antenna 5 is introduced <sup>into</sup> the etching chamber  
1 through a dielectric body 8. Further, between the  
antenna 5 and an electrode 9, a volume combination



electric field is generated, and this electric field becomes an effective plasma generation source.

The frequency of the microwave<sup>energy</sup> is set to [have] a range of from 300 MHz to 1 GHz and has a band area in which [an]<sup>the</sup> electron temperature of the plasma [has]<sup>is</sup> a low temperature of from 0.25 eV to 1 eV.

In this embodiment according to the present invention, [the]<sup>a</sup> frequency band [of a]<sup>in the</sup> vicinity of 450 MHz can be employed. Further, as the dielectric body 8, a quartz or an alumina<sup>material</sup> can be employed. Further, a heat resistant polymer having a small dielectric loss, such as a polyimide etc., can be employed<sup>as well</sup>.

The electrode for mounting a wafer (the wafer mount electrode or [a] sample table) 9 is provided [on a lower]<sup>below</sup> [portion of] the gas supply plate 4, and a wafer 10 [being]<sup>representing</sup> a sample is supported<sup>on the sample table 9</sup> through [an] electrostatic adsorption. To draw [into] the ions in the plasma to the wafer 10, a high frequency bias is applied to the wafer mount electrode 9 from a high frequency power supply 11.

Further, the temperature control of an inner wall of the etching chamber 1 [being]<sup>representing</sup> the vacuum processing chamber, which is an essential feature according to the present invention, is carried out at a temperature adjustment side wall 12 of the etching chamber 1.

To the temperature adjustment side wall 12,<sup>although</sup> not shown in<sup>the</sup> figure, a coolant medium which [has]<sup>is</sup> temperature controlled is introduced<sup>so that</sup> [and] the temperature adjustment

side wall 12 is maintained at a constant temperature. In this embodiment according to the present invention, the constant temperature in the temperature adjustment side wall 12 is set to [have] 30 °C.

5 The etching gas and ~~(the)~~ reaction <sup>products</sup> ~~(product)~~ are deposited <sup>on</sup> ~~(in)~~ the inner wall of the etching chamber 1 and <sup>also</sup> ~~(also)~~ they are deposited at the periphery and, a downstream area of the wafer mount electrode 9 <sup>so that a</sup> ~~(and the)~~ deposition film <sup>is generated which is the</sup> ~~[become the generation]~~ origin of the foreign <sup>matter in the etching chamber</sup> ~~(matters)~~.

10 Accordingly, it is necessary to ~~(clean)~~ periodically remove the deposition film, however, it is not always easy to remove <sup>a</sup> ~~(the)~~ strongly adhered deposition film. Herein, in this embodiment according to the present invention, the cleaning of the deposition film is carried out ~~(again)~~ using an exclusive cleaning apparatus.

15 The <sup>time used for establishing a vacuum state by</sup> ~~(transfer to a vacuum)~~ evacuation of the etching chamber 1, which has <sup>been</sup> ~~(opened)~~ to the air, <sup>for cleaning</sup> is important from an aspect of <sup>the</sup> ~~(a shortage of a)~~ non-operation, of the apparatus and further from an aspect of an improvement of <sup>the</sup> ~~(a)~~ productivity <sup>of the apparatus</sup>.

20 Accordingly, it is desirable <sup>to prevent</sup> ~~(that)~~ the deposition film <sup>from adhering on</sup> ~~(is tried to not adhere)~~ a portion where <sup>a</sup> ~~(the)~~ component exchange-over is not carried out easily, and <sup>to try to move</sup> ~~(that)~~ the component to which the deposition film has adhered ~~(is)~~ <sup>as a component which can be easily replaced by</sup> ~~(tried to exchange over)~~ another ~~(prepared cleaning)~~ clean component. <sup>In this way</sup> ~~(As a result)~~, the ~~(air)~~ opening <sup>for cleaning</sup> time in the etching chamber 1 can be shortened, and <sup>reduction</sup> ~~(a shortage)~~ of the

*cleaning and* [vacuum] evacuation, *time* [after that] can be *achieved* [improved].

In this embodiment according to the present invention, *to prevent* [not to adhere] the deposition film, *from adhering* to the downstream region of the etching chamber 1, *a* [an] deposition film [use] cover 13 is provided *in* [on] the downstream region of the temperature adjustment side wall 12 of the etching chamber 1.

To the cover 13, a vacuum evacuation [use] and [a] wafer delivery [use] opening portion is provided. Since the deposition film *can be removed with* [are recovered by] this cover 13, the adhesion of the deposition film in the downstream region of the temperature adjustment side wall 12 can be reduced.

A vacuum chamber 15 is connected directly to the etching chamber 1, and a turbo molecular pump 14 having an evacuation speed of from 2000 L/s to 3000 L/s is installed in the vacuum chamber 15. Further, *although* not shown *the* in figure, to an opening portion of the turbo molecular pump 14, a vacuum evacuation speed adjustment [use] conductance valve 16 is installed, and this evacuation speed adjustment [use] conductance valve 16 is used for separating the turbo molecular pump 14 during the [air] *chamber* open time, or the evacuation speed adjustment [use] conductance valve 16 is used for not opening *the chamber to* the air.

Next, an example of [an] oxide film etching using the plasma processing apparatus of this embodiment according to the present invention will be explained.

To the etching chamber 1 which is (vacuum) evacuated  
 (at) <sup>to</sup> a high vacuum condition, <sup>although</sup> not shown in <sup>the</sup> figure, the  
 wafer 10 is carried in from a transfer chamber by a  
 transfer arm, and the wafer 10 is delivered <sup>onto</sup> (on) the wafer  
 5 mount electrode 9.

The transfer arm is <sup>then retracted,</sup> (retarded) and, after a valve  
 arranged between the etching chamber 1 and a transfer  
 chamber <sup>has been</sup> closed, the wafer mount electrode 9 is  
<sup>raised to</sup> (ascended and stopped) a position where the etching is <sup>to be</sup>  
 10 carried out. In the case of this embodiment according to  
 the present invention, <sup>the</sup> (a) distance between the wafer 10  
 and the gas introduction plate 4 (an electrode <sup>interval</sup> (between)  
 (distance)) is set to from 50 mm to 100 mm.

<sup>\*</sup> As the etching gas, a mixture gas comprised of Ar,  
 15 (and) <sup>and</sup> C<sub>4</sub>F<sub>8</sub>, O<sub>2</sub> is used, and the respective flow amounts are  
 500 sccm, 10 sccm and 5 sccm (are introduced). The  
 pressure of the etching gas is 2 Pa. <sup>the</sup> (An) output of <sup>the</sup> UHF  
 microwave power supply <sup>6</sup> is 1 kW, and (an) <sup>the</sup> output of a bias  
 power supply 11 to the wafer 10 is 600 W.

20 (The) <sup>A</sup> current is applied to the coil 2 and a resonance  
 magnetic field having 0.016 T of UHF <sup>energy at</sup> (microwave having) 450  
 MHZ is generated between the gas supply plate 4 and the  
 wafer mount electrode 9 (namely the wafer 10). Next, the  
 microwave power supply 6 is operated. <sup>Due</sup> (According) to the  
 25 electron cyclotron resonance <sup>phenomenon</sup>, a strong plasma is  
 generated in <sup>the</sup> ECR area having <sup>a</sup> (the) resonance magnetic field  
 strength of 0.016 T.

To improve the uniformity of the etching characteristic, it is necessary to <sup>ensure that the</sup> [uniform an] incident ion density on <sup>the</sup> [a] surface of the wafer 10, and when <sup>is uniform,</sup> ECR is positioned as stated <sup>the</sup> [in] above and <sup>the</sup> [a] shape of ECR area is formed <sup>with</sup> [a] raised <sup>portion extending</sup> [shape] toward <sup>required</sup> [a side of] the wafer 10,   
 5 [as a result] the uniformity of the ion current density can be attained.

After a spark of the <sup>plasma</sup> [plasm], not shown in <sup>the</sup> figure, from a direct current power supply which is connected   
 10 directly in parallel with the high frequency power supply 11, a high voltage is applied to the wafer mount electrode 9, and then the wafer 10 is <sup>electrostatically attracted</sup> [electrostatic] <sup>and held on</sup> [adsorbed] to the wafer mount electrode 9.

At a rear face of the [electrostatic adsorbed] wafer   
 15 10, helium (He) gas is introduced, and the temperature adjustment of the wafer 10 is carried out between <sup>the</sup> [a] wafer <sup>mounting</sup> [mount] face of the wafer mount electrode 9, which <sup>by a</sup> [has] is temperature controlled [according to the] coolant medium, and the wafer 10, through the helium (He) gas.

Next, the high frequency power supply 11 is [tried to]   
 20 [be] operated, <sup>and a</sup> [the] high frequency bias is applied to the wafer mount electrode 9. Accordingly, <sup>ions are</sup> [to the wafer 10] [the ion is] incident vertically from the <sup>plasma onto the wafer 10</sup> [plasm]. In <sup>a processing with</sup> [the] oxide film etching, it is necessary to carry out [the] high   
 25 energy <sup>ions</sup> [ion incident].

In this embodiment, according to the present invention, a high frequency bias voltage  $V_{pp}$  (the voltage

between the maximum peak and the minimum peak) <sup>has</sup> [is made] a value of from 1000 V to 2000 V. In <sup>response to</sup> [accordance with] the impact <sup>of</sup> [due to the] <sup>ions with the wafer surface</sup> high energy <sup>ion</sup>, the temperature of the wafer 10 <sup>rises</sup> [is arisen].

5 In [the] oxide film etching, since the selection ratio is [become] high <sup>at</sup> [in the] higher temperature <sup>values,</sup> the etching characteristic has a superior characteristic, <sup>and so</sup> the wafer temperature is adjusted to a value [having] <sup>of</sup> several 10 °C.

10 However, since it is necessary to carry out the <sup>processing with</sup> [incident of the] high energy <sup>ions</sup> [ion], <sup>the</sup> [a] heat input amount to the wafer 10 is large, and <sup>so</sup> the coolant medium temperature of the wafer mount electrode 9 is set <sup>in the</sup> [to a] vicinity of [-] -20 °C.

At <sup>this</sup> [the same] time, when the bias voltage is applied to 15 the wafer 10, the etching is started. <sup>and the</sup> The etching is finished <sup>within</sup> [under] a predetermined etching time. Or, <sup>though</sup> not shown in <sup>the</sup> figure, by monitoring <sup>the</sup> [a] plasma luminescence strength change of the reaction <sup>products</sup> [product] and further judging <sup>the</sup> [a] finish point of the etching, an etching finish 20 time <sup>can be determined,</sup> [is requested] and, after a suitable over etching <sup>has been</sup> [is] performed, then the etching is finished.

The <sup>completed at</sup> [finish of the] etching is a time when the application of the high frequency bias voltage is stopped. Simultaneously with this, the supply of the 25 etching gas is stopped.

However, it is necessary to provide a process in which the electrostatically <sup>held</sup> [adsorbed] wafer 10 is <sup>released</sup> [adsorbed].

from the wafer mount electrode 9, and <sup>for this purpose,</sup> (as) an electric  
 adsorption gas, <sup>such as</sup> (an) Ar etc., is supplied. By stopping the  
 supply of the electrostatic adsorption voltage, and <sup>then connecting the</sup> (after)  
 (an) electric supply line (is connected) to an earth ground, <sup>while</sup>  
 5 maintaining the discharge of the microwave <sup>energy,</sup> an electric  
 adsorption time <sup>of</sup> (having) 10 seconds <sup>allocated</sup> (degree) is <sup>prepared</sup>.  
 Accordingly, the electric charges on the wafer 10 are  
 adsorbed by the earth ground through the plasma <sup>and,</sup> as a  
 result, the wafer 10 can be removed easily.

10 When the electric adsorption process is <sup>ended</sup> (finished),  
 the supply of the electric adsorption gas is stopped, and  
 also the supply of the microwave <sup>energy</sup> is stopped. Further,  
 the current supply to the coil 2 is stopped. Further, [a]  
 [height of] the wafer mount electrode 9 is <sup>lowered</sup> (descended), until  
 15 <sup>the surface thereof reaches</sup> [to] the wafer delivery position.

After that, for some time, the etching chamber 1 is  
 (vacuum) evacuated until <sup>is achieved</sup> (the high vacuum. At a time point  
<sup>when state has been reached</sup> [of] the high vacuum, [evacuation is completed], the valve  
 between the etching chamber 1 and the transfer chamber is  
 20 opened (and), the transfer arm is inserted <sup>therein</sup>, and then the  
 wafer 10 is delivered and is carried out. In (a) case (of)  
<sup>there is to be</sup> (an existence of) a next etching process, a new wafer is  
 carried in and the etching is performed again according  
 to the above-stated procedures.

25 In <sup>the</sup> <sup>^</sup> <sup>description</sup> above, the representative flow of the etching  
 process was explained.

<sup>the</sup> The electron temperature of UHF band microwave ECR

plasma is <sup>in</sup> a range of from 0.25 eV to 1 eV and the dissociation of  $C_4F_8$  <sup>which is</sup> [being] the etching gas <sup>does progress</sup> (is) not very <sup>much</sup> progressed. The dissociation of  $C_4F_8$  is <sup>a</sup> complicated <sup>process</sup> [one], <sup>in which</sup> (however) the gas species which contributes <sup>to</sup> the etching is <sup>first</sup> dissociated from  $CF_3$  to  $CF_2$ , <sup>then</sup> [in next]  $CF$  is generated, and finally  $F$  is generated. As a result, the <sup>higher</sup> [more] the electron temperature <sup>[is high]</sup>, the more the plasma becomes <sup>rich in F</sup> [one having F-rich plasma].

As stated in the <sup>Background of the Invention</sup> [prior art item], to ensure the <sup>proper</sup> selection ratio in the oxide film etching, <sup>in the deposition of a film</sup> on the foundation silicon [the deposition film are adhered and] it is necessary to restrain the etching according to the high <sup>ion energy</sup> [energy] incident. Namely, since <sup>on the wafer</sup> (the) high energy ions are incident, when there <sup>is</sup> (are) no deposition film, there <sup>is</sup> a possibility <sup>that</sup> [in which] the etching <sup>will progress</sup> [is progressed] according to a physical sputter.

As a result, <sup>for the etching</sup> to progress [the etching], it is necessary to supply [the] high energy ions to the <sup>bottom of a</sup> hole [bottom], however to ensure the <sup>required</sup> selection ratio, it is necessary to supply [the] radicals which form <sup>a</sup> (the) deposition film. It is said that the radicals for forming the deposition film are  $CF_3$  and  $CF_2$ .

<sup>On the other hand</sup> [In reversely],  $F$  radicals form  $SiF_4$  etc. and the foundation silicon is <sup>caused</sup> [made] to be etched. As a result, to perform [the] high selection ratio etching, it is necessary to make  $CF_2/F$  ( $CF_2$ - $F$  ratio) large. In the case of UHF



band microwave ECR plasma, <sup>since</sup> ~~the~~ the electron temperature is low, the generation amount of F is small, <sup>and a</sup> ~~the~~ plasma having <sup>amount of</sup> ~~the~~ plentiful  $CF_3$ ,  $CF_2$  and CF is formed.

Accordingly, as shown in the case of <sup>a</sup> ~~the~~ high electron temperature and <sup>a</sup> ~~the~~ high density plasma, to supply  $CF_2$  and  $CF_3$ , which become insufficient <sup>due to</sup> ~~by~~ the excessive progress of the ~~plasma~~ dissociation of the plasma, it is unnecessary to heat the inner wall of the etching chamber 1 <sup>to</sup> more than 200 °C.

As the necessary points for <sup>achieving a</sup> ~~the~~ fine <sup>processing</sup> ~~practicing~~ correspondence etching, <sup>the</sup> following points are stated, namely (1) under <sup>a</sup> ~~the~~ low electron temperature, the plasma dissociation is restrained suitably and <sup>a</sup> ~~the~~ plasma having <sup>a</sup> ~~the~~ large  $CF_2/CF$  ( $CF_2$ -CF ratio) is generated <sup>the</sup>; (2) the discrepancy <sup>between a</sup> ~~from~~ 90° angle <sup>and</sup> ~~of~~ the ion incident angle is restrained <sup>to a value</sup> small, and a tapering formation of the etching shape <sup>and</sup> ~~the~~ (3) even <sup>when</sup> the etching is repeated many times, the fluctuation of the etching characteristic is small <sup>etc.</sup>.

In addition to the above, an item relating to the etching characteristics is an important development problem, however, in the present specification, such an item is not mentioned.

(1)  
The above-stated <sup>a</sup> ~~the~~ (1) item <sup>for the necessary points</sup> for the fine <sup>processing</sup> ~~practicing~~ correspondence etching is solved by the use of <sup>the</sup> UHF band microwave plasma etching apparatus according to the present invention.

(2)  
As to the above-stated <sup>a</sup> ~~the~~ (2) item <sup>for the necessary</sup>

points for the fine practicing correspondence etching, a  
 main cause is that the orbit<sup>of the ions</sup> is displaced<sup>displaced</sup> according to<sup>with</sup>  
 the collision of the ions and the<sup>gas</sup> [molecular] in the  
 vapor phase, and<sup>so</sup> it is effective to lower the pressure to  
 5 lessen the<sup>occurrence of such collisions</sup> collision of the molecular.

Since<sup>the</sup> UHF band microwave plasma etching apparatus  
 according to the present invention [is used the<sup>uses</sup> electron  
 cyclotron resonance, it is possible to generate the  
 plasma under the<sup>low</sup> low pressure.

10 As to the above-stated (3) item, for the necessary  
 points for the fine practicing<sup>processing</sup> correspondence etching, it  
 is necessary to prevent<sup>prevent fluctuation of</sup> [not fluctuate] the etching characteristic  
 even<sup>when number of</sup> the etching [time numbers] are repeated<sup>operations which is in the order of</sup> [at] several  
 hundred [order]; namely, it is necessary to restrain the  
 15 time lapse change.

A main cause of the time lapse change is the time  
 fluctuation of the [gas]<sup>of gas</sup> kinds, which are discharged from  
 the deposition film which<sup>adheres</sup> [adhere] to the inner wall (the  
 side wall, the ceiling, etc) and the<sup>other</sup> components of the  
 20 etching chamber 1. [In concretely, the temperature  
 fluctuation of the members to be subjected, such as the  
 side wall<sup>represents a</sup> [occupies the] large cause<sup>of the problem</sup> against

As a countermeasure of the restraint of the time  
 lapse change, basically the apparatus is formed<sup>so as</sup> to prevent<sup>prevent fluctuation</sup> [not]  
 25 [fluctuate] the desorption and adsorption phenomenon of the  
 deposition film [of] the wall face [according to the] using  
 temperature control, however, in accordance with the various

plasma generation systems, the wall face area <sup>used</sup> [necessary] to form [as] the apparatus differs.

The relationship between the etching chamber height and the side face area is shown in Fig. 2. In the narrow electrode type plasma [type] apparatus, the height of the etching chamber is low, and also the area of the side wall face is narrow. On the other hand, in the high density plasma [type] apparatus, the height of the etching chamber is high, and also the area of the side wall face is wide.

In <sup>the</sup> UHF type ECR apparatus according to the present invention, the height of the etching chamber (the electrode <sup>interval</sup> [between distance]) and the area of the side wall are positioned <sup>relative to the other types of apparatus,</sup> intermediately, and the apparatus occupies <sup>a</sup> [the] region which is suitable for [the] oxide film etching.

Namely, according to the present invention, the height of the etching chamber (the electrode <sup>interval</sup> [between] [distance]) and the area of the side wall has a middle value <sup>in the range</sup> [having] 30 mm - 100 mm of the narrow electrode (about 30 mm) and the microwave ECR induction type (more than 100 mm).

The height of the etching chamber, namely the electrode <sup>interval</sup> [between distance], is a distance of from 50 mm to 100 mm, and the reaction <sup>products</sup> [product] generated by the etching <sup>are</sup> [is] re-dissociated and [is] re-incident <sup>on</sup> [to] the wafer

10. <sup>for</sup> (With) the above stated reasons, the etching characteristic of the oxide film <sup>is influenced</sup> [receives an influence],

however, this is caused by making the most suitable performance to the influence degree, such as the re-dissociation and the <sup>incidence</sup> [incident] of the reaction <sup>product</sup> [product] etc. with the etching characteristic of the oxide film. →

5      Namely, in this embodiment according to the present invention, the electrode <sup>interval</sup> [between distance] is [formed] <sup>set</sup> [according] to a predetermined distance which is determined by a relative relationship of <sup>the</sup> [a] mean free <sup>ion path in the</sup> stroke at <sup>a</sup> [a] vicinity <sup>at a</sup> [of the] pressure of 2 Pa.

10      Since the electrode <sup>interval</sup> [between distance] is <sup>set to</sup> [formed by] the above stated distance, the pressure distribution on the face of the wafer 10 can be <sup>made uniform</sup> [uniformed]. In a case where the wafer diameter is <sup>large, such as</sup> [formed largely] from 200 mm to 300 mm, the difference in pressure between the center and  
15 the periphery of the wafer 10 can be small [fully]. →

Further, since the conductance, which depends on the <sup>interval,</sup> electrode <sup>a high speed of evacuation of the chamber to a</sup> [between distance] is <sup>attained</sup> [formed] large, <sup>and,</sup> (the) high vacuum [evacuation speed] can be <sup>during which</sup> [obtained large fully], as a result, the <sup>products remain in the chamber</sup> [stay] time <sup>of</sup> the etching gas and the reaction  
20 [product] can be shortened easily.

<sup>widened</sup> In a case where the area of the side wall is further <sup>that</sup> [wide], there is a possibility [in which] the adhesion amount of the deposition film becomes large <sup>with</sup> (and then) the <sup>of influence on</sup> result that the [influence] degree <sup>an</sup> (to) the etching characteristic becomes  
25 large. In <sup>requirements</sup> [the] apparatus for maintaining <sup>a</sup> [the] high density plasma, according to the [request] of the plasma generation method, it is necessary to form the height of the etching

chamber to <sup>fall in a</sup> [a] range from 100 mm to 200 mm. →

Accordingly, the <sup>ratio of</sup> [rate in which] the area of the side wall <sup>to the</sup> [occupies largely in a] whole area of the etching chamber is high, and <sup>so</sup> the influence <sup>on</sup> [during] the fluctuation of the etching gas and the deposition of the reaction <sup>products on</sup> [product in] the side wall <sup>will be</sup> [is] large.

As [the] methods for restraining this influence, there are methods in which the temperature fluctuation of the side wall is <sup>reduced</sup> [made to lessen] or the side wall is heated <sup>to a</sup> [under the] high temperature to <sup>prevent a</sup> [not adhere the] deposition film. <sup>from adhering thereto</sup>

Further, as stated <sup>above</sup> [in the former portion], in [the] <sup>a</sup> apparatus using [the] high density plasma source, since the electron temperature is high, <sup>an</sup> [the plasma having] F-rich plasma is generated, <sup>therefore,</sup> [to ensure] <sup>a proper</sup> [the] selection ratio, it is necessary to reduce the gas species which adheres to the side wall, or it is necessary to promote <sup>a</sup> [the] gas discharge from the deposition film. <sup>As</sup> [as] a result, it is necessary to <sup>raise</sup> [make] the side wall <sup>to a</sup> [at the] high temperature.

<sup>for</sup> [With] the above stated reasons, in <sup>a</sup> [the] high electron temperature and [the] high density plasma etching apparatus, the side wall is heated <sup>to</sup> [at] 200 °C degree and the temperature fluctuation is <sup>maintained within</sup> [temperature adjusted at] a range of  $\pm 2$  °C. →

However, it is difficult technically to heat the side wall <sup>to a</sup> [at the] high temperature <sup>of</sup> more than 200 °C, and <sup>also</sup> [also] it is difficult technically to restrain, with [the]

to as little

high accuracy, the temperature fluctuation, [such] as  $\pm 2^\circ \text{C}$ .  
 Further, <sup>such a technique</sup> (and further it) invites <sup>a</sup> (the) complicated structure <sup>for</sup> (in) the  
 apparatus and a problem in (the) reliability (and the rise) <sup>as well as an increase</sup>  
 in cost. Further, the side wall <sup>comprises</sup> (has the same meaning to)  
 5 the <sup>entire</sup> inner wall of the etching chamber, (the side wall) and  
 includes the top plate and other portions which contact  
 (to) the plasma.

(Further, in) <sup>in</sup> a portion (is one) where the deposition  
 film adheres, (when such a portion) <sup>but which</sup> is not contacted  
 10 directly <sup>by the plasma</sup>, since this portion has a possibility for  
 affecting the etching characteristic, (in compliance of)  
 (the apparatus,) it is necessary to take <sup>such portion</sup> fully into (an)  
<sup>consideration</sup> (attention).

Further, in the apparatus according to the present  
 15 invention, since the side wall <sup>is</sup> (has) from 50 mm to 100 mm  
 (degree), (in) the downstream region, <sup>thereof</sup> (it) can (admit) hardly (the) <sup>comprise a</sup>  
 region where the deposition film is adhered.

As a result, <sup>for</sup> (as the) oxide film plasma etching  
 (apparatus), it is desirable to provide <sup>an</sup> (the) apparatus in  
 20 which (the) fluctuation of the etching characteristic is  
 not generated, <sup>when</sup> even the temperature adjustment accuracy in <sup>the control of</sup>  
 the side wall temperature is mitigated.

In UHF type ECR plasma apparatus according to the  
 present invention, it is unnecessary to <sup>increase</sup> (heighten) the side  
 25 wall temperature to improve the selection ratio. There  
 is <sup>the advantage that</sup> (a merit in which) the side wall temperature can be  
 established (according to) <sup>from</sup> the view point of the restraint

of the time lapse change.

Fig. 3 shows the results in a case <sup>in which</sup> (when) the temperature of the deposition film <sup>was</sup> (is) changed 1 °C, <sup>and</sup> the gas discharge amounts from the deposition film were

5 measured.

<sup>seen from these results</sup> It is (understood) that when the temperature of the deposition film is high, <sup>a large</sup> (there appear much gas) amount <sup>of gas</sup> (which) is discharged <sup>with a</sup> (according to the) temperature fluctuation of 1 °C. It is supposed that when the gas

10 which corresponds to the flow amount of 0.01 sccm by the conversion calculation of the flow amount of the etching gas, there is a possibility that the etching characteristic is <sup>influenced</sup> (given the influence) and the temperature adjustment range of the side wall temperature <sup>at</sup> (of) this time is shown <sup>on</sup> (in) the right side in Fig. 3.

In <sup>the</sup> (a) case of <sup>a wall temperature of</sup> 200 °C, when the side wall is not controlled <sup>to</sup> (at)  $\pm 2$  °C, the fluctuation of the gas discharge amount becomes less than 0.01 sccm. On the other hand, <sup>when</sup> the side wall temperature is controlled <sup>to</sup> less than 120 °C, even the side wall temperature changes <sup>cause a small</sup> (the) change in the gas discharge amount (is small).

20 Namely, it is understood that even <sup>when</sup> the control accuracy of the side wall temperature is (controlled with)  $\pm 5$  °C and  $\pm 10$  °C, the gas discharge for giving (the) <sup>an</sup> influence to the etching characteristic does not occur.

In the etching apparatus according to the present invention, the side wall temperature is established <sup>within</sup> (at) a

range of from 10 °C to 120 °C. Preferably, it is controlled from the room temperature 20 °C to 50 °C.

With this temperature range, since the etching chamber is not heated <sup>to a</sup> [at the] high temperature, there <sup>is the advantage</sup> (are) <sup>merits</sup> that the <sup>used for</sup> [dimension] size of the apparatus is small, and the materials <sup>materials</sup> (of), the vacuum sealing and, [the material] having <sup>a</sup> [the] different thermal expansion coefficient can be used freely, and the temperature control can be performed easily.

According to the present invention, <sup>is provided</sup> [it employs the] system, <sup>a</sup> in which [the] coolant medium which is connected to the temperature adjustment means is introduced to the side wall. By the employment of <sup>such a</sup> [the above stated] system, the temperature control <sup>performance</sup> [performance] can be carried out, <sup>to</sup> less than  $\pm 10$  °C.

Further, Fig. 3 shows the results in which the discharge amounts from the deposition film were <sup>measured</sup> [searched]. When the side wall temperature <sup>reaches a</sup> [becomes the] high temperature <sup>of</sup> [having] more than 200 °C, since the adhesion amounts of the deposition film themselves become small, in <sup>an</sup> [the] apparatus having <sup>a</sup> [the] high temperature control in which <sup>a</sup> [the] deposition film <sup>does</sup> [are] not <sup>adhere</sup> [adhered], as shown in <sup>an</sup> (an) <sup>the</sup> example <sup>in</sup> [in] Fig. 3, [the] substantial gas discharge amounts become small.

The stability of the gas discharge amounts and the <sup>magnitude</sup> [largeness] of the fluctuation amounts into which the consideration of the adhesion amounts is taken are shown



in Fig. 4.

In Fig. 4, the horizontal axis indicates the side wall temperature of the etching chamber, and the <sup>vertical</sup> [horizontal] axis indicates the relative <sup>magnitude</sup> [largeness degree] <sup>of influence on</sup> [about] the deposition film amount, the (influence) degree [to] the time lapse change and the gas discharge amount.

The gas discharge amount from the deposition film increases abruptly <sup>for side wall temperatures which exceed</sup> [from a vicinity which exceeds over] 200 °C. On the other hand, the [adhesion] amount of the <sup>which adheres</sup> deposition film to the side wall (the deposition speed) reduces gradually in <sup>proportion to an increase in the</sup> [proportional to the high] temperature and decreases abruptly <sup>for temperatures in excess</sup> [from the vicinity] of 200 °C.   
 The reason <sup>for this</sup> is <sup>that</sup> [why] when the temperature exceeds [over] 200 °C, and further when the temperature exceeds [over more] 300 °C, the deposition film <sup>does</sup> [is] not <sup>adhere</sup> [adhered] to the side wall.

Accordingly, in the temperature range of the <sup>AREA</sup> [region] 1 in Fig. 4, since the <sup>side wall</sup> temperature is low, the influence for referring to the etching characteristic to the deposition film of the side wall is small. Further, in the <sup>AREA</sup> [region] 3 in Fig. 4, since the temperature is high, the gas discharge amount from the unit deposition film is <sup>large</sup> [much], however <sup>a</sup> [the] deposition film <sup>will</sup> [is] hardly <sup>adhere</sup> [adhered], and, as a result, the gas discharge amount is small <sup>and</sup> [the] influence <sup>on</sup> [to] the etching characteristic is small.

However, in the <sup>AREA</sup> [region] 2 in Fig. 4, which <sup>represents an</sup> [is the] <sup>AREA 1 and AREA 3</sup> [the both], the intermediate temperature range between

deposition film is comparatively large and the gas discharge amount is <sup>large and</sup> [much], as a result, the temperature fluctuation of the side wall <sup>has a large</sup> [is given the] influence [largely to] <sup>on</sup> the etching characteristic.

- 5 Taking into [the] consideration [from] the above-stated points, to restrain the time lapse change, the side wall temperature is set to the <sup>AREA</sup> [region] 1 or the <sup>AREA</sup> [region] 3. The temperature range of the <sup>AREA</sup> [region] 1 is less than 120 °C, and in the <sup>AREA</sup> [region] 3, the temperature range is more than 200 °C
- 10 [and] <sup>while</sup> in the <sup>AREA</sup> [region] 2 the temperature range is from 120 °C to 200 °C.

According to this embodiment (according to) <sup>of</sup> the present invention, <sup>the temperature of</sup> the side wall is established <sup>in</sup> the temperature range of the <sup>AREA</sup> [region] 1 in Fig. 4. Further, <sup>above-described</sup> from the principle, the side wall temperature may be <sup>established in</sup> [establish to] the low temperature <sup>range</sup>, however, taking into consideration <sup>ease in establishing</sup> the temperature establishment is easily the temperature <sup>providing a</sup> and [the] coolant medium <sup>without creating</sup> [is not presented] [to the drew] condensation, the lower limitation

15 <sup>established in</sup> temperature is set to 10 °C.

- 20 Fig. 5 shows <sup>the etching speed fluctuation in a</sup> [that in] UHF type ECR plasma etching apparatus [of the embodiment according to the present] [invention, <sup>the</sup> the etching speed fluctuation is shown] in a case of using [the] <sup>a</sup> mixture gas containing Ar and C<sub>4</sub>F<sub>8</sub>, <sup>and in which</sup> [the] continuous etching is carried out.

In this <sup>case</sup> [time], [since] the temperature adjustment of the side wall is not carried out, <sup>and so</sup> the temperature

fluctuation <sup>riser</sup> (is risen accompanying) with the discharge time of the plasma [and is risen] to 60 °C degree from [the] room temperature. The temperature fluctuation is  $\pm 20$  °C [degree]. The etching speed of the silicon nitride at the etching starting time <sup>is</sup> [becomes] high, <sup>as a result of</sup> [it can be admitted] the fluctuation of the etching characteristic.

On the other hand, Fig. 6 shows the etching characteristic in <sup>a</sup> case where the temperature adjustment of the side wall is carried out. →

10 After the etching chamber is opened to the air and <sup>evacuation of the chamber</sup> is carried out [the vacuum evacuation], <sup>but</sup> without [the] [performance of the] covering [about] the inner portion of the etching chamber by the deposition film and also the process for presenting the regular state, [regardless] immediately <sup>after</sup> the etching is started, the etching characteristic is stable from the starting time of the etching, and the fluctuation after that is not hardly <sup>in evidence</sup> [admitted]. Further, the side wall temperature fluctuation at this time is within  $\pm 5$  °C.

20 As understood from the above <sup>a</sup> stated results, in UHF type ECR plasma etching apparatus, [according to the] [performance of the] <sup>by performing a</sup> temperature adjustment of the side wall, <sup>an</sup> [the] extremely stable etching characteristic can be obtained.

25 Further, in this embodiment according to the present invention, it is <sup>assumed</sup> [explained on the assumption] that <sup>a</sup> UHF type ECR plasma etching apparatus is used, however, when

the plasma source is suited for the etching of <sup>an</sup> [the] oxide film, it is not limited to <sup>a</sup> UHF type ECR plasma etching apparatus.

Namely, when the electron temperature in the plasma is the low <sup>for example, an</sup> electron temperature <sup>when a</sup> [having] less than 1 eV, and <sup>is possible to</sup> [further the] high density plasma is used, for example, it <sup>an</sup> [can] employ <sup>a</sup> [the] apparatus using <sup>a</sup> [the] pulse plasma source in which the application of the microwave is carried out intermittently.

Further, it <sup>is possible to</sup> <sup>an</sup> [can] employ <sup>an</sup> [the] apparatus using <sup>a</sup> [the] plasma source in which <sup>an</sup> [the] induction type plasma, except <sup>but that the</sup> for the microwave is pulse driven. When the side wall of the etching chamber of these plasma sources is established at a range of 10 °C to 120 °C, it is possible to obtain <sup>a</sup> [the] superior oxide film etching characteristic, and, further, it is possible to exhibit <sup>a</sup> [the] stable characteristic during <sup>a</sup> [the] long period <sup>of operation</sup>.

Further, the temperature adjustment of the side wall is exemplified <sup>by</sup> using <sup>a</sup> [the] coolant medium, however <sup>the invention</sup> [it] is not limited <sup>to use of a</sup> <sup>since</sup> the coolant medium, it can employ any one of <sup>various types</sup> the [use] of <sup>a</sup> [the] compulsory cooling using <sup>a</sup> [the] water cooling and <sup>a</sup> [the] vapor cooling, <sup>a</sup> [the] heater, <sup>or</sup> <sup>a</sup> [the] lamp heating using <sup>rays</sup> [the] infrared [ray].

To summarize, the temperature <sup>within</sup> [range] must be formed <sup>with</sup> the range of 10 °C to 120 °C. With the above stated temperature range, even <sup>when</sup> the temperature adjustment range of the side wall is  $\pm 5$  °C degree, <sup>a</sup> [the] fully stable

etching characteristic can be obtained.

According to the etching characteristic, even<sup>when</sup> the temperature adjustment range of the side wall is  $\pm 10^\circ\text{C}$  [degree], (the)<sup>a</sup> stable etching characteristic can be obtained, and [further] the temperature adjustment can be carried out extremely easily.

According to the present invention, since [the]<sup>a</sup> superior oxide film etching characteristic can be obtained and [further the]<sup>a</sup> stable characteristic can be obtained during<sup>a</sup> [the] long period<sup>of operation</sup>, the following [merits]<sup>advantages</sup> can be expected.

Namely, the yield can be improved and the throughput can be improved. Further, since the temperature adjustment is established<sup>in a</sup> [to at the] low temperature<sup>range</sup> of from  $10^\circ\text{C}$  to  $120^\circ\text{C}$ , the inconvenience in which the size of the etching chamber is made large<sup>due to</sup> [by the] thermal expansion can be avoided.

For example, the line expansion coefficient of the aluminum alloy which is largely<sup>used</sup> in the etching chamber is  $24 \times 10^{-6}\text{K}^{-1}$ ; on the other hand, (in the)<sup>for</sup> alumina and quartz, the respective line expansion coefficients<sup>are</sup> [is]  $6 \times 10^{-6}\text{K}^{-1}$  and  $0.41 \times 10^{-6}\text{K}^{-1}$ .

Since the line expansion coefficients differ so much, when the etching chamber is heated<sup>to produce</sup> [according to] the plasma<sup>a</sup> discharge or the etching chamber is temperature controlled compulsively at [the]<sup>a</sup> high temperature, the differences in the [dimension] sizes between the materials

become large <sup>, making</sup> [and then] it [is] necessary to [devise]  
<sup>design the chamber to avoid</sup> structurally [the avoidance of the] thermal expansion.

Further, the <sup>size of</sup> (size) change in the vacuum sealing  
<sup>exerts an</sup> portion [gives the] influence <sup>on</sup> [to] the sealing

5 characteristic, and [further] the heat resistant  
 performance of the elastomer <sup>which forms</sup> [being] the seal material <sup>also</sup>  
 becomes a problem.

When the temperature <sup>reaches a</sup> (becomes high to the) level <sup>of</sup> more  
 than 150 °C, the possibility <sup>that</sup> [in which] the life of the  
 10 seal material <sup>will be</sup> [presents] short becomes high.

As stated [in] above, <sup>are caused</sup> [there cause the] various problems,  
 [in which the avoidance appears] due to [the] high  
 temperature, and <sup>addition of</sup> the heat resistant performance [is added]  
<sup>causes</sup> structurally, [and] the cost <sup>of the apparatus to increase</sup> [increases].